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Influencing Factors on Power Losses in Electric Distribution Network

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***Abstract*— *Line losses reduction greatly affects the performance of the electric distribution network. This paper aims to identify the influencing factors causing power losses in that network. Newton-Raphson method is used for the loss assessment and the Sensitivity analysis by approach One-Factor-At-A-Time (OAT) for the influencing factors identification. Simulation with the meshed IEEE-30 bus test system is carried out under MATLAB environment. Among the 14 parameters investigated of each line, the result shows that the consumed reactive powers by loads, the bus voltages and the linear parameters are the most influencing on the power losses in several lines. Thus, in order to optimize these losses, the solution consists of the reactive power compensation by using capacitor banks; then the placement of appropriate components in the network according to the corresponding loads; and finally, the injection of other energy sources into the bus which recorded high level losses by using the hybrid system for instance.*

***Keywords*— Active power losses, Electric power distribution, Influencing factors, Newton Raphson, Power losses, Sensitivity Analysis**

I. INTRODUCTION

Electricity demand throughout the world doesn't cease to grow up. This is due to the growth of population and industrialization altogether. To meet the electricity needs of all consumers and in order to realize the sustainable energy planning, almost of the distribution system operators are looking to improve energy performance of their networks. One of the great difficulties facing the distributors is the on-line power losses. It means that the performance of electric network depends on power losses minimization.

Most of previous work have just informed about the two kinds of losses in electrical network; that are the technical losses and the non-technical losses [1, 2] .Some papers highlighted the different kind of method concerning losses assessment [3, 4]; whereas some researchers used any different optimization method for the reduction of losses [5, 6], [7], by means of using Genetic Algorithms compensation with capacitors banks [8]. Other literature proposed the importance of network reconfiguration [9] without knowing the factors that caused the issue. However, few of these literatures mentioned a detailed analysis on the identification of key factors influencing losses in the grid, except the study of Ali Nourai [10] but it focuses only on the load levelling from the peak to the off-peak period.

That is the reason why, in this paper, recognizing the source of losses in the network and identifying the influencing factors are the primary step before processing into the network optimization.

Therefore, a meshed distribution from IEEE-30 bus test system is tested and analyzed in this work. The analysis consists to identify the influencing factors of each branch in that electric distribution network. The method of Newton Raphson Load flow (NRLF) combined with the One-Factor-At-A- Time (OAT) of the sensitivity analysis are chosen to perform this analysis. NRLF is used for losses assessment in each branch of the grid whereas OAT is for modifying each input parameters of the model by ±10% around its initial value and observing the effect of each operated modification on the output which is the active power losses. This work is concluded by discussing the results and giving new perspectives for losses reduction and network optimization.

II. POWER LOSSES IN ELECTRIC DISTRIBUTION NETWORK

Electricity generated by the power plants is delivered to consumers throughout the transmission and distribution power lines. During the process of electricity transmission into the consumers, losses are unavoidable. It implies that only some part of electricity transmitted is consumed.

As we know that electric network mainly includes three sectors: the production, the transport network and the distribution network. This last sector accounts higher losses rather than in production and transport sector. From generation to distribution in an electric system, the overall loss threshold considered acceptable for international experts is 10 to 15%. This percentage includes technical losses and non-technical losses. Normally, active power losses should be around 3 to 6%; but in reality, it is about 10% in developed countries and 20% in developing countries [6].

Losses in electric distribution network can be divided into two categories: technical losses and non-technical losses. Non-technical losses are from several sources including power theft, un-billed accounts, errors and inaccuracies in electricity metering systems, lack of administration, financial constraints [2].

Besides, Technical losses in the distribution system are caused generally by the physical properties of the network elements (conductors, equipment used for distribution line, transformer) [4]. The heat dissipation due to current flowing in the electrical network created line losses, which is well known as joule effect: $P_L = RI^2$

Losses in transformer are due to iron losses and copper losses. The iron losses are caused by the cores magnetizing inductance (Foucault current and Hysteresis) that dissipated a power, whereas Copper losses are by the winding impedance inside the transformer.

In other words, the technical losses result from the active and reactive power flow in the network. Active power losses are due to the over loading of lines characterized by the resistance. Low voltages and variation of powers flows in each bus can produce also these active losses. Otherwise, reactive power losses are produced by the reactive elements (the reactance of the line).

On the one hand, total active and reactive power losses are computed with:

$$P_{loss} = \sum_{i=1}^{n_{br}} R_i |I_i|^2 \tag{1}$$

$$Q_{loss} = \sum_{i=1}^{n_{br}} X_i |I_i|^2 \tag{2}$$

Where P_{loss} and Q_{loss} are respectively the active andreactive power losses ; n_{br} is the number ofbranches of the system, I_i the current flowing through the branch, R_i the resistance of the branch iand X_i the reactance of the branch i.

On the other hand, the overall active power losses of the entire network are obtained by the differencebetween the active generated power and the active consumed power.

$$Total\ active\ power\ losses = P_g - P_c \tag{3}$$

For similar reason, the total reactive power losses of the network are equivalent to the reactive generation or consumption of the network. That is to say the sum of the reactive powers injected or absorbed by the generators is equal to the sum of reactive power consumed or generated by the load added the sum of reactive generation or consumption of the network.

$$\sum Q_g = \sum Q_c + \text{reactive generation or consumption of the net}$$

III. METHODOLOGY FOR POWER LOSSES ASSESSMENT AND INFLUENCING FACTORS IDENTIFICATION

3.1 ASSESSMENT OF POWER LOSSES BY NEWTON RAPHSON METHOD

Different technics are used to assess the power losses. As we see in the expressions (3) and (4), the Global losses of the network can be deduced through these equations, in condition that all injected powers (active and reactive) and bus voltage (V,θ) in each bus are known. But the problem is we cannot get easily the voltage at different buses of the system because of the interdependence between the bus voltage and the different powers at load bus. The main difficulty in evaluating power losses in distribution network is the nonlinear relationship between the injections powers at the buses and their variables associated [3]. For this reason, resolution by the power flow (Load flow) is required for a good assessment. Several methods have been used for load flow calculation such as the GAUSS-SEIDEL method, the NEWTON-RAPHSON method, the bi- factorization method of K-ZOLLENKOPF, the relaxation method, the DC-Flow method, ... Among these different methods, we prefer to use the Newton Raphson method because this method converges much faster. In addition, this method can transform the original non-linear problem into a sequence of linear problems whose solutions approach the solutions of the original problem. The solution to the power flow problem begins with identifying the known and unknown

variables in the system. These variables (P, Q, V,θ) are the characteristics of each bus in the network that are respectively the active power, the reactive power, the voltage magnitude and the voltage angle. These four variables are dependent on the type of bus. So, two of them must be known in each bus. If P and V are known, that means a generator is connected to the bus, it is called a Generator Bus. In contrary, if no generators are connected to the bus, it is the Load bus (or PQ Bus). Aside this, resolving load flow problem needs one bus that chosen arbitrarily and the value of the voltage (V, Θ) must be fixed before a program execution. This bus is known as Slack-bus.

The common process of load flow computation is summarized on the organigram 1 (Fig. 1) while the specificity of NRLF method [11] and its algorithm details are shown in Fig. 2.

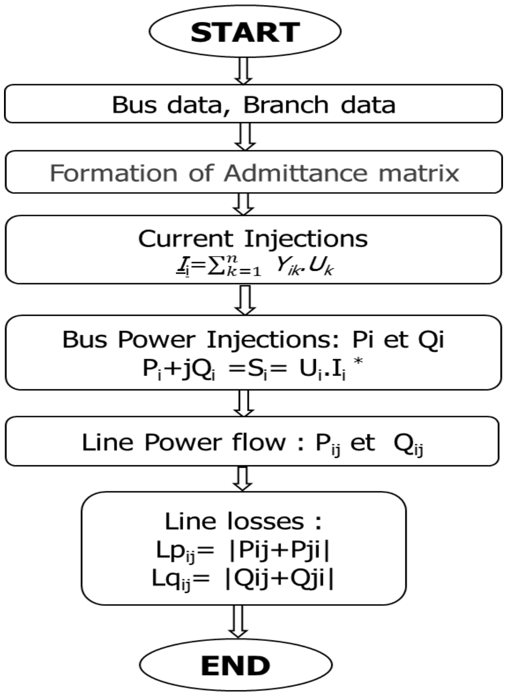

Fig. 1: Organigram of Load Flow

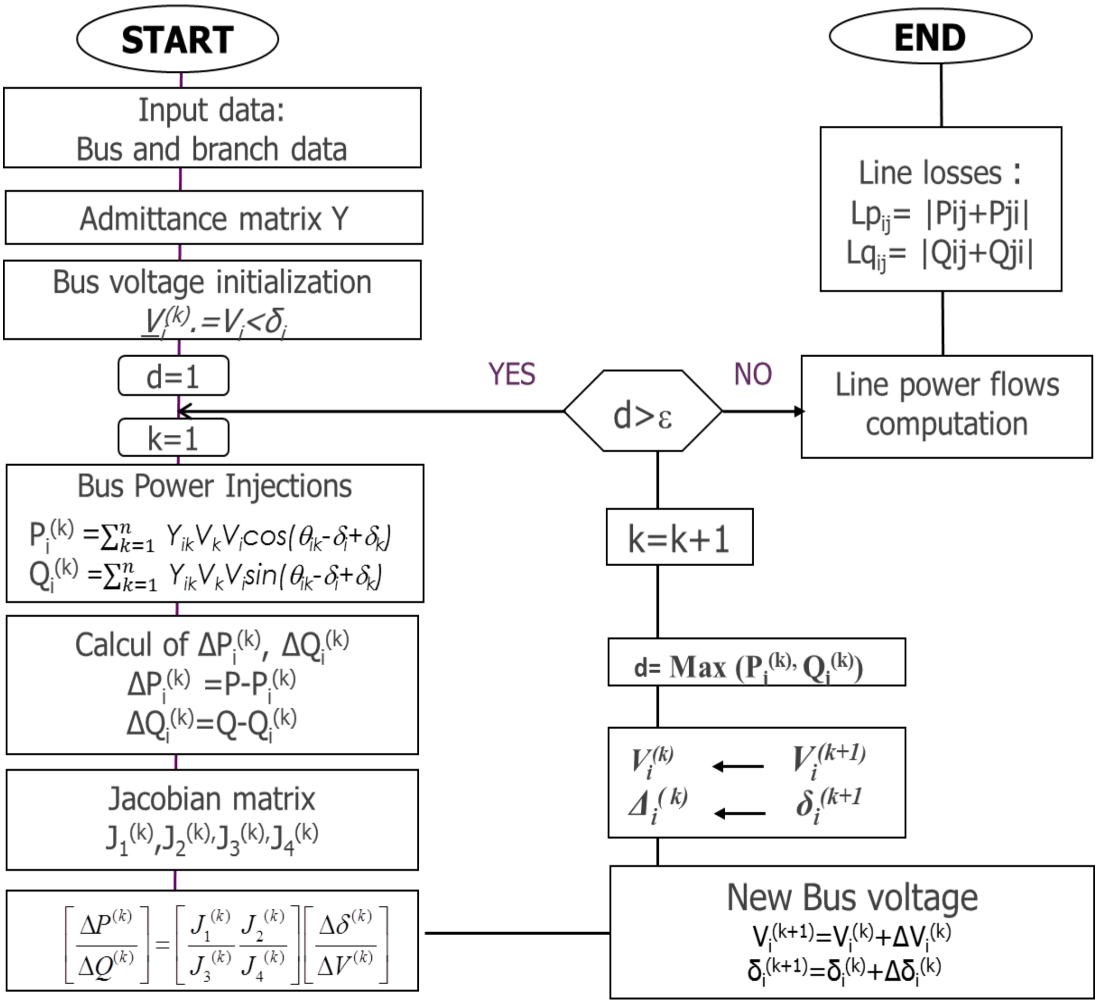

Fig. 2: Organigram of Newton Raphson Load Flow

3.2. SENSITIVITY ANALYSIS BY OAT METHOD

The sensitivity analysis SA is a mathematical tool that observes the output of a model in relation to the variations of different input factors and quantifies their influences on the model. According to Jolicoeur [12], it happens often a lot of parameters in a complex mathematical model, and they do not have the same degree of influence on the model outputs. Some have more important contribution than others. Thus, a sensitivity analysis can help predict the effect of each parameter on model results and classify them according to their degree of sensitivity [13]. There are mainly three different methods of SA: the Local Sensitivity Analysis (LSA), the Global Sensitivity Analysis (GSA) and the Screening Designs (SD). The using of each kind of method depends on the objectives that users want. These methods are widely described with Bertrand and al. in [14] and Kleijnen and al. in [15].

What we are interested in these methods is the “Screening Designs” (SD) which contains the “One-Factor-At-A-Time” method because it is efficient when a model has many input parameters

[12]. It has a purpose to arrange the most important factors among many others that may affect a particular output of a given model. Although OAT approach is to assess the relative importance of input factors with uncertainty, and applied only in linear model [13], this is the reason why Newton Raphson method has been chosen to transform the non-linearity of the load flow problem into a linear application.

In this case, all the linear parameters and the bus characteristics have been contributed to the analysis, because it consists to find the effect of each parameter on active power loss in each branch.

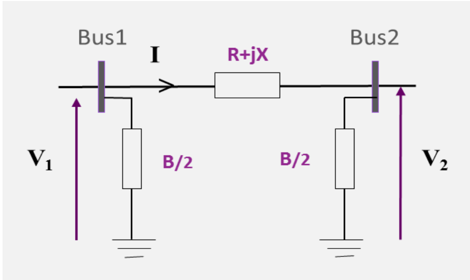

Fig. 3: A two-bus system

Totally, 14 parameters are studied except the voltage angle θ because it was taken automatically as zero during the bus voltage initialization (principle of slack bus).

Table 1: Parameters with their variation range

N°		Symbole	Description of the parameter	Variation range	Unit
1		R	Resistance of the branch	[0 :0.33] in pu	Ω/km
2		X	Reactance of the branch	[0 :0.61] in pu	Ω/km
3		B	Susceptance of the branch	[0 :0.06] in pu	µS/km
4		a	Transformer rate	[0.9 :1]in pu	
5		V(NI)	Voltage Magnitude in the initial bus	[0.94 :1.6] in pu	kV
6		V(NE)	Voltage Magnitude in the initial bus	[0.94 :1.6] in pu	kV
7		Pg(NI)	Generated Active power in the initial bus (Node Initial)	[40 :300]	MW
8		Pg(NE)	Generated Active power in the extreme bus(Node extreme)	[40 :300]	MW
9		Qg(NI)	Generated Reactive power in the initial bus	[-40 :50]	MVar
10		Qg(NE)	Generated Active power in the extreme bus	[-40 :50]	MVar
11		Pc(NI)	Consumed Active power in the initial bus	[0 :95]	MW
12		Pc(NE)	Consumed Active power in the extreme bus	[0 :95]	MW
13		Qc(NI)	Consumed Reactive power in the initial bus	[0 :30]	MVar

14		**Qc(NE)**	Consumed Reactive power in the extreme bus	[0 :30]	MVar
15		**θ**	Voltage angle		°

The relative variation rate $V_r(p)$ [16], and the sensitivity index *SI(p)* [12], in a parameter *p* of a model can be computed as these following expressions:

$$V_r(p) = \left|\frac{S_2 - S_1}{S_1}\right| 100 \quad (5)$$

$$SI(p) = \frac{S_{avg}}{E_{avg}} E_2 - E_1 \quad (6)$$

Where:

- E_1 is the initial input parameter;
- E_2 is the tested input value (: ±v% modification; "v" is a given percentage, it depends on the parameters. For the linear parameters R, X, B and the different powers; a variation of +/- 10% is acceptable. And for the bus voltage, a +/- 4% is acceptable because the variation range in p.u for voltages are between 0.90 and 1.10)
- E_{avg} the average between E_1 and E_2
- S_1, S_2 are respectively the outputs value corresponding to E_1 and E_2;
- S_{avg} is the average between E_1 and E_2.

IV. RESULTS

4.1. MESHED DISTRIBUTION NETWORK IEEE-30 BUS

The case study is the 30 Bus Test meshed distribution network from the IEEE [18]. It represents a portion of the American Electric Power System (in the Midwestern US) as of December, 1961. The data was kindly provided by Iraj Dabbagchi of AEP and entered in IEEE Common Data Format by Rich Christie at the University of Washington in August 1993.

This system has 30 buses, 41 branches, 2 synchronous generators in bus 1 and 2 that produce 300,2 MW altogether, 4 synchronous compensators in buses 5,8,11,13 and 4 transformers 132kV/33kV in branches 11,12,15 and 36.

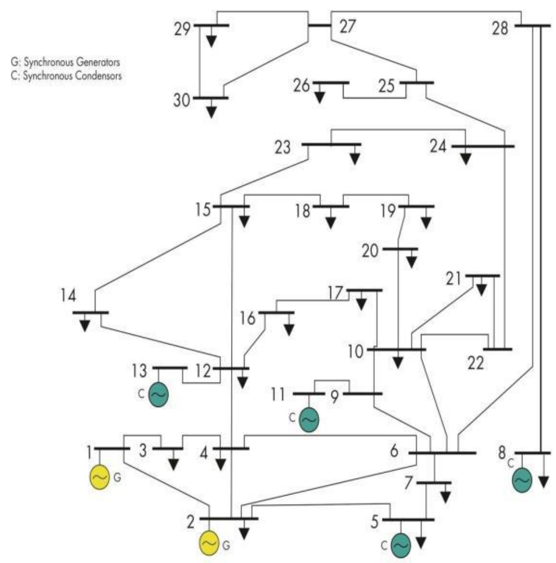

Fig. 4: One-line diagram of the IEEE 30bus

Table 2: Bus data of meshed network IEEE-30 BUS

Bus	Bus Type	V (p.u)	θ	Pg (MW)	Qg (MVAR)	Pc (MW)	Qc (MVAR)
1	1	1.060	0	260.2	-16.1	0	0
2	2	1.043	0	40	50	21.7	12.7
3	3	1	0	0	0	2.4	1.2
4	3	1	0	0	0	7.6	1.6
5	2	1.010	0	0	37	94.2	19
6	3	1	0	0	0	0	0
7	3	1	0	0	0	22.8	10.9
8	2	1.010	0	0	37.3	30	30
9	3	1	0	0	0	0	0
10	3	1	0	0	0	5.8	2

11	2	1.082	0	0	16.2	0	0
12	3	1	0	0	0	11.2	7.5
13	2	1.071	0	0	10.6	0	0
14	3	1	0	0	0	6.2	1.6
15	3	1	0	0	0	8.2	2.5
16	3	1	0	0	0	3.5	1.8
17	3	1	0	0	0	9	5.8
18	3	1	0	0	0	3.2	0.9
19	3	1	0	0	0	9.5	3.4
20	3	1	0	0	0	2.2	0.7
21	3	1	0	0	0	17.5	11.2
22	3	1	0	0	0	0	0
23	3	1	0	0	0	3.2	1.6
24	3	1	0	0	3	8.7	6.7
25	3	1	0	0	0	0	0
26	3	1	0	0	0	3.5	2.3
27	3	1	0	0	0	0	0
28	3	1	0	0	0	0	0
29	3	1	0	0	0	2.4	0.9
30	3	1	0	0	0	10.6	1.9

Table 3: Branch data of meshed network IEEE-30 BUS

Branch	**Bus i**	**Bus j**	**R (p.u)**	**X (p.u)**	**B (p.u)**	**a**
Branch 1	**1**	**2**	0.0192	0.0575	0.0254	1
Branch 2	**1**	**3**	0.0452	0.1652	0.0204	1
Branch 3	**2**	**4**	0.0570	0.1737	0.0184	1
Branch 4	**3**	**4**	0.0132	0.0379	0.0042	1
Branch 5	**2**	**5**	0.0472	0.1983	0.0209	1
Branch 6	**2**	**6**	0.0581	0.1763	0.0187	1
Branch 7	**4**	**6**	0.0119	0.0414	0.0045	1
Branch 8	**5**	**7**	0.0460	0.1160	0.0102	1
Branch 9	**6**	**7**	0.0267	0.0820	0.0085	1
Branch 10	**6**	**8**	0.0120	0.0420	0.0045	1
Branch 11	**6**	**9**	0	0.2080	0	0.978
Branch 12	**6**	**10**	0	0.5560	0	0.969
Branch 13	**9**	**11**	0	0.2080	0	1
Branch 14	**9**	**10**	0	0.1100	0	1
Branch 15	**4**	**12**	0	0.2560	0	0.932

Branch 16	**12**	**13**	0	0.1400	0	1
Branch 17	**12**	**14**	0.1231	0.2559	0	1
Branch 18	**12**	**15**	0.0662	0.1304	0	1
Branch 19	**12**	**16**	0.0945	0.1987	0	1
Branch 20	**14**	**15**	0.2210	0.1997	0	1
Branch 21	**16**	**17**	0.0524	0.1923	0	1
Branch 22	**15**	**18**	0.1073	0.2185	0	1
Branch 23	**18**	**19**	0.0639	0.1292	0	1
Branch 24	**19**	**20**	0.0340	0.0680	0	1
Branch 25	**10**	**20**	0.0936	0.2090	0	1
Branch 26	**10**	**17**	0.0324	0.0845	0	1
Branch 27	**10**	**21**	0.0348	0.0749	0	1
Branch 28	**10**	**22**	0.0727	0.1499	0	1
Branch 29	**21**	**22**	0.0116	0.0236	0	1
Branch 30	**15**	**23**	0.1000	0.2020	0	1
Branch 31	**22**	**24**	0.1150	0.1790	0	1
Branch 32	**23**	**24**	0.1320	0.2700	0	1
Branch 33	**24**	**25**	0.1885	0.3292	0	1
Branch 34	**25**	**26**	0.2544	0.3800	0	1
Branch 35	**25**	**27**	0.1093	0.2087	0	1
Branch 36	**28**	**27**	0	0.3960	0	0.968
Branch 37	**27**	**29**	0.2198	0.4153	0	1
Branch 38	**27**	**30**	0.3202	0.6027	0	1
Branch 39	**29**	**30**	0.2399	0.4533	0	1
Branch 40	**8**	**28**	0.0636	0.2000	0.0214	1
Branch 41	**6**	**28**	0,0169	0,0599	0.0065	1

4. 2. POWER LOSSES BY NRLF

As shown in table 4, the different powers flowing in each bus are obtained.

Table 4: Injected, generated and consumed powers in each bus

Bus	V	Teta	Pi	Qi	Pg	Qg	Pc	Qc
1	1.060	0	260.92	-17.106	260.923	-17.106	0.000	0.000
2	1.043	-5.347	18.3	35.063	40.000	47.763	21.700	12.700
3	1.021	-7.545	-2.4	-1.200	-0.000	0.000	2.400	1.200
4	1.012	-9.299	-7.6	-1.600	0.000	0.000	7.600	1.600
5	1.010	-14.153	-94.2	16.955	-0.000	35.955	94.200	19.000
6	1.012	-11.086	0	-0.000	0.000	0.000	0.000	0.000
7	1.003	-12.872	-22.8	-10.900	-0.000	0.000	22.800	10.900
8	1.010	-11.802	-30	0.693	0.000	30.694	30.000	30.000

9	1.051	-14.113	0	0.000	0.000	0.000	0.000	0.000
10	1.044	-15.699	-5.8	17.000	-0.000	19.000	5.800	2.000
11	1.082	-14.113	0	16.112	0.000	16.112	0.000	0.000
12	1.057	-14.958	-11.2	-7.500	0.000	-0.000	11.200	7.500
13	1.071	-14.958	0	10.392	0.000	10.392	0.000	0.000
14	1.042	-15.850	-6.2	-1.600	-0.000	0.000	6.200	1.600
15	1.037	-15.939	-8.2	-2.500	-0.000	0.000	8.200	2.500
16	1.044	-15.544	-3.5	-1.800	-0.000	0.000	3.500	1.800
17	1.039	-15.860	-9	-5.800	-0.000	-0.000	9.000	5.800
18	1.028	-16.549	-3.2	-0.900	-0.000	-0.000	3.200	0.900
19	1.025	-16.721	-9.5	-3.400	0.000	0.000	9.500	3.400
20	1.029	-16.523	-2.2	-0.700	0.000	-0.000	2.200	0.700
21	1.032	-16.143	-17.5	-11.20	0.000	-0.000	17.500	11.200
22	1.032	-16.129	0	-0.000	-0.000	-0.000	0.000	0.000
23	1.027	-16.328	-3.2	-1.600	-0.000	0.000	3.200	1.600
24	1.021	-16.503	-8.7	-2.400	-0.000	4.300	8.700	6.700
25	1.018	-16.102	0	-0.000	-0.000	-0.000	0.000	0.000
26	1.001	-16.521	-3.5	-2.300	-0.000	0.000	3.500	2.300
27	1.025	-15.594	0	0.000	0.000	0.000	0.000	0.000
28	1.010	-11.745	0	0.000	0.000	0.000	0.000	0.000
29	1.005	-16.818	-2.4	-0.900	-0.000	-0.000	2.400	0.900
30	0.994	-17.696	-10.6	-1.900	-0.000	0.000	10.600	1.900
Total power			17.523 MW	20.911 MVar	300.923 MW	147.110MVar	283.400 MW	126.200 MVar

The results show that the sum of the injected active powers in every bus represents also the same value as the *table 5* shows. That is the total active power losses in that network.

$$\sum P_i = \sum P_g - \sum P_c = (300.923 - 283.400)$$

$$\sum L_{P_{ij}} = 17.523\ MW. \quad (7)$$

This result justifies the two ways for power losses assessment as mentioned in equation (3) and (4)

Table 5: Different power flows and losses between bus i and j

Bus *i*	**Bus *j***	***Pij***	***Pji***	***Qij***	***Qji***	**Active loss *Lpij***	**Reactive loss *Lqji***
1	2	173,1323	-167,9542	-18,1051	33,6124	5,1781	15,5073
1	3	87,7903	-84,6742	6,2574	5,1314	3,1161	11,3892
2	4	43,6294	-42,6178	5,2035	-2,1208	1,0116	3,0826
3	4	82,2742	-81,4163	-3,7639	6,2269	0,8578	2,4629
2	5	82,2857	-79,3408	4.0330	8,3391	2,9449	12,3721
2	6	60,3391	-58,3936	1,3956	4,5078	1,9455	5,9035

4	6	72,1656	-71,5256	-17,5893	19,8156	0,6399	2,2263
5	7	-14,8592	15,0214	11,7887	-11,3796	0,1622	0,4091
6	7	38,2022	-37,8214	-1,1932	2,3626	0,3807	1,1694
6	8	29,5229	-29,4197	-3,1776	3,5391	0,1033	0,3615
6	9	27,6158	-27,6158	-18,6362	20,8404	0.0000	2,2042
6	10	15,7788	-15,7788	-5,4231	6,8873	0.0000	1,4642
9	11	0.0000	0.0000	-15,6508	16,112	0.0000	0,4612
9	10	27,6158	-27,6158	6,7571	-5,9522	0.0000	0,8048
4	12	44,2686	-44,2686	-16,7104	21,9171	0.0000	5,2067
12	13	0.0000	0.0000	-10,2601	10,3919	0.0000	0,1318
12	14	7,8714	-7,7966	2,4345	-2,2791	0,0747	0,1554
12	15	17,9205	-17,7019	6,9303	-6,4998	0,2185	0,4305
12	16	7,2767	-7,2225	3,3453	-3,2313	0,0542	0,1139
14	15	1,5966	-1,5905	0,6791	-0,6736	0,0061	0,0055
16	17	3,7225	-3,7105	1,4313	-1,4032	0,0121	0,0281
15	18	6,0513	-6,0118	1,7324	-1,6521	0,0395	0,0803
18	19	2,8118	-2,8066	0,7521	-0,7417	0,0051	0,0103
19	20	-6,6933	6,7101	-2,6582	2,6918	0,0168	0,0335
10	20	8,9904	-8,9101	3,5711	-3,3918	0,0803	0,1793
10	17	5,3037	-5,2895	4,4337	-4,3967	0,0142	0,0371
10	21	15,7236	-15,6138	9,8441	-9,6077	0,1098	0,2363
10	22	7,5769	-7,5252	4,4916	-4,3849	0,0517	0,1066
21	22	-1,8862	1,8868	-1,5923	1,5936	0,0006	0,0013
15	23	5,0411	-5,0095	2,9411	-2,8771	0,0316	0,0638
22	24	5,6384	-5,5956	2,7914	-2,7249	0,0427	0,0664
23	24	1,8095	-1,8033	1,2771	-1,2649	0,0061	0,0125
24	25	-1,3009	1,3085	1,5895	-1,5762	0,0076	0,0133
25	26	3,5445	-3,5001	2,3665	-2,3001	0,0445	0,0664
25	27	-4,8531	4,8785	-0,7903	0,8389	0,0254	0,0486
28	27	18,1592	-18,1591	-3,3361	4,6151	0.0000	1,2791
27	29	6,1894	-6,1035	1,6677	-1,5055	0,0858	0,1622
27	30	7,0913	-6,9298	1,6614	-1,3575	0,1614	0,3038
29	30	3,7035	-3,6701	0,6055	-0,5424	0,0334	0,0631
8	28	-0,5803	0,5806	-0,2032	0,2041	0,0002	0,0007
6	28	18,7995	-18,7397	-2,9369	3,1485	0,0597	0,2117
					Total power losses	**17.523 MW**	**68.867 MVAR**

4.3. INFLUENCING FACTORS ON POWER LOSSES

As we observed on the global representation of the Sensitivity index (Fig. 5); many high peaks have been appeared that indicate the most influencing parameter in the corresponding branch (Tables 6, 7).

A *SI* positive means that the variation of the inputs value is the same direction as the variation in the output whereas a *SI* negative represents an inverse effect between the inputs and the output factors. It could be seen that each branch has its influencing factor which differs from each other.

Table 6: Sensitivity Index of the 14 parameters

	R	*X*	*B*	*a*	*V(NI)*	*V(NE)*	*Pg(NI)*	*Pg(NE)*	*Qg(NI)*	*Qg(NE)*	*Pc(NI)*	*Pc(NE)*	*Qc(NI)*	*Qc(NE)*
Branch 1	0,781	-1,77	0	0	-2,266	-2,121	0	-0,389	0	-0,001	0	2,382	0	0
Branch 2	0,847	-1,842	0	0	-2,305	-2,289	0	0	0	0	0	2,881	0	0
Branch 3	0,788	-1,782	0	0	-2,078	-2,184	0,147	0	-0,012	0	2,094	2,020	0,032	0,412
Branch 4	0,764	-1,758	0	0	-2,296	-2,312	0	0	0	0	2,897	2,318	0,007	0,338
Branch 5	0,882	-1,877	0	0	-2,207	-2,245	0,027	0	-0,0024	-0,002	2,197	2,239	0,014	0,425
Branch 6	0,786	-1,780	0	0	-2,141	-2,271	0,084	0	0,001	0	2,221	0	0,005	0
Branch 7	0,833	-1,827	0	0	-2,498	-2,480	0	0	0	0	2,151	0	0	0
Branch 8	0,705	-1,699	0	0	-2,310	-3,452	0	0	-0,071	0	0,36	0,359	0,503	1,739
Branch 9	0,790	-1,785	0	0	-2,112	-2,116	0	0		0	0	2,530	0	1,290
Branch 10	0,835	-1,829	0	0	-3,445	-3,302	0	0	0	-0,057	0	2,532	0	0,852
Branch 11	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Branch 12	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Branch 13	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Branch 14	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Branch 15	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Branch 16	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Branch 17	0,594	-1,588	0	0	-2,142	-2,142	0	0	0	0	2,133	2,163	0,326	1,538
Branch 18	0,558	-1,552	0	0	-2,090	-2,090	0	0	0	0	2,173	2,187	0,391	2,948
Branch 19	0,601	-1,595	0	0	-1,656	-1,655	0	0	0	0	2,289	1,982	0,647	3,668
Branc	-0,049	-	0	0	-	-	0	0	0	0	2,54	2,520	0,786	7,167

h 20		0,848			1,514	1,514								
Branch 21	-2,894	1,532	0	0	7,919	7,919	0	0	0	0	-0,909	-1,03	-2,61	-1,546
Branch 22	0,580	-1,574	0	0	-1,966	-1,963	0	0	0	0	2,284	2,373	0,363	0
Branch 23	0,575	-1,569	0	0	-1,568	-1,568	0	0	0	0	2,622	2,59	0,585	3,573
Branch 24	0,568	-1,562	0	0	-2,736	-2,736	0	0	0	0	1,812	1,884	0,213	0
Branch 25	0,638	-1,632	0	0	-2,624	-2,624	0	0	0	0	1,735	1,963	0,214	0
Branch 26	0,721	-1,715	0	0	-3,273	-3,273	0	0	0	0	0,690	0	0,561	0,755
Branch 27	0,616	-1,610	0	0	-2,365	-2,365	0	0	0	0	1,690	1,690	0,665	2,823
Branch 28	0,588	-1,582	0	0	-2,393	-2,393	0	0	0	0	1,732	0	0,648	0
Branch 29	0,565	-1,570	0	0	-1,619	-1,619	0	0	0	0	0,597	0	1,069	0
Branch 30	0,575	-1,569	0	0	-1,688	-1,688	0	0	0	0	0	2,545	0,737	4,234
Branch 31	0,375	-1,369	0	0	-2,634	-2,634	0	0	0	0	1,856	2,095	0	3,235
Branch 32	0,583	-1,578	0	0	-0,467	-0,466	0	0	0	0	3,696	3,365	1,231	11,25
Branch 33	0,468	-1,463	0	0	-1,155	-1,155	0	0	0	0	3,305	0	-0,045	0
Branch 34	0,339	-1,333	0	0	-2,432	-2,432	0	0	0	0	0	1,484	0	3,807
Branch 35	0,536	-1,530	0	0	-2,557	-2,557	0	0	0	0	0	0	0	0
Branch 36	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Branch 37	0,528	-1,523	0	0	-2,448	-2,448	0	0	0	0	0	2,60	0	0
Branch 38	0,526	-1,520	0	0	-2,458	-2,458	0	0	0	0	0	0	0	1,036
Branch 39	0,528	-1,523	0	0	-2,471	-2,471	0	0	0	0	2,690	2,181	0,127	0,890
Branch 40	0,684	-1,687	0,13	0	-17,78	-18,74	0	0	2,208	0	-10,11	0	0,778	0
Branch 41	0,838	-1,833	0	0	-2,156	-2,156	0	0	0	0	0	0	0	0

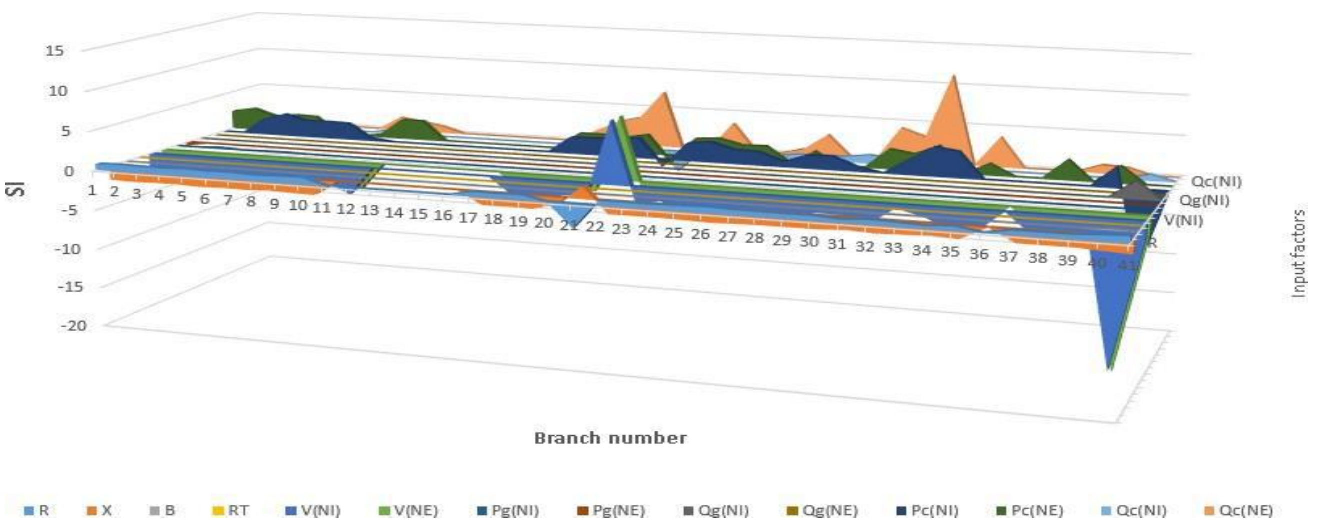

Fig. 5: Global representation of the factor effect on each branch according to the SI values

Table 7: Relative variation rate of the 14 parameters

	R	*X*	*B*	*a*	*V(NI)*	*V(NE)*	*Pg(NI)*	*Pg(NE)*	*Qg(NI)*	*Qg(NE*	*Pc(NI)*	*Pc(NE)*	*Qc(NI)*	*Qc(NE)*
Branch 1	7,653	20,414	0	0	9,115	9,115	4,188	4,188	0,018	0,018	25,97	25,970	0,098	0,177
Branch 2	8,378	21,442	0	0	9,279	9,279	1,610	1,611	0,017	0,017	26,051	26,051	0,034	1,893
Branch 3	7,799	20,743	0	0	8,772	8,771	1,414	1,414	0,129	0,129	22,479	22,479	0,319	2,529
Branch 4	7,446	20,433	0	0	9,310	9,301	1,651	1,651	0,021	0,021	26,221	26,221	0,057	2,073
Branch 5	8,739	21,885	0	0	9,203	9,205	0,261	0,262	0,025	0,024	23,723	23,723	0,137	1,990
Branch 6	7,769	20,643	0	0	9,266	9,266	0,804	0,804	0,015	0,015	24,010	24,010	0,049	2,552
Branch 7	8,332	21,049	0	0	10,09	10,09	0,922	0,922	0,228	0,228	24,108	24,108	0,051	0,108
Branch 8	6,948	19,643	0	0	14,33	14,33	1,136	1,136	0,753	0,753	3,511	3,511	4,915	8,767
Branch 9	7,914	20,742	0	0	8,532	8,532	0,555	0,555	0,027	0,027	27,664	27,666	0,162	5,959
Branch 10	8,284	21,309	0	0	14,29	14,29	0,009	0,009	0,598	0,598	27,430	27,430	1,675	4,247
Branch 11	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Branch 12	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Branch 13	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Branch 14	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Branch 15	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Branch 16	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Branch 17	5,818	18,252	0	0	8,656	8,656	0,046	0,046	1,311	1,311	22,186	22,186	3,358	9,781
Branch 18	5,446	17,734	0	0	8,438	8,438	0,086	0,086	1,764	1,764	22,653	22,653	4,039	12,27
Branch	5,927	18,367	0	0	6,626	6,626	0,215	0,215	4,619	4,619	24,010	24,010	6,783	22,01

19														
Branch 20	0,523	9,359	0	0	6,044	6,043	0,196	0,196	6,517	6,517	26,559	26,559	9,703	32,70
Branch 21	24,07	14,905	0	0	26,59	26,59	29,619	29,619	23,99	23,99	9,368	9,368	24,15	7,519
Branch 22	5,672	18,122	0	0	7,907	7,907	0,162	0,162	2,895	2,895	23,7759	23,779	4,206	13,38
Branch 23	5,642	17,977	0	0	6,266	6,265	0,351	0,351	5,953	5,953	26,605	26,605	6,363	22,74
Branch 24	5,575	17,925	0	0	11,19	11,19	0,125	0,125	2,294	2,295	17,853	17,853	1,818	1,770
Branch 25	6,297	18,801	0	0	10,70	10,70	0,094	0,094	1,583	1,584	18,664	18,664	2,063	3,066
Branch 26	7,030	19,717	0	0	13,53	13,54	0,169	0,169	6,508	6,508	7,030	7,030	7,495	3,881
Branch 27	6,079	18,548	0	0	9,602	9,601	0,009	0,009	0,173	0,174	18,137	18,137	6,544	15,91
Branch 28	5,791	18,190	0	0	9,721	9,720	0	0.012	0.065	0.065	18,631	18,63	6,369	15,84
Branch 29	5,723	18,373	0	0	6,476	6,475	0	0	2,108	2,108	6,0241	6,024	10,54	17,17
Branch 30	5,631	18,007	0	0	6,763	6,763	0,142	0,142	4,942	4,942	25,728	25,728	8,717	29,44
Branch 31	3,643	15,539	0	0	10,75	10,75	0,056	0,056	0,967	0,967	22,979	22,979	4,805	15,25
Branch 32	5,720	18,123	0	0	1,825	1,825	0,325	0,325	14,504	14,50	39,667	39,667	15,61	65,43
Branch 33	4,579	16,677	0	0	4,579	4,579	0,380	0,380	13,580	13,58	38,827	38,827	11,85	24,68
Branch 34	3,282	15,101	0	0	9,889	9,889	0,002	0,002	0,321	0,321	17,451	17,451	7,489	17,63
Branch 35	5,233	17,552	0	0	10,42	10,42	0,145	0,145	3,087	3,087	15,376	15,376	3,948	0,110
Branch 36	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Branch 37	5,171	17,412	0	0	9,956	9,956	0,002	0,003	0,231	0,232	23,284	23,284	2,019	6,087
Branch 38	5,137	17,405	0	0	9,998	9,998	0,003	0,003	0,233	0,233	23,650	23,650	1,723	5,459
Branch 39	5,169	17,417	0	0	10,05	10,05	0,003	0,003	0,236	0,236	24,118	24,118	1,354	4,673
Branch 40	6,779	19,491	1,27	1,27	113,9	113,9	0,847	0,747	23,30	23,30	227,542	227,542	93,64	278,8
Branch 41	8,371	21,399	0	0	8,715	8,715	0,030	0,030	0,169	0,169	22,903	22,903	0,497	1,046

Some specific branches are presented in Fig. 6 to Fig. 9 to show the effect of the parameters through V_r and *SI* values.

The most highlights branches are the branch 21 and the branch 40 which are affected by the bus voltage and the reactive powers in the extreme bus.

In the first branch of which the two generators are connected to the buses, there is no effect of the reactive powers as shown in the Fig. 6 (a), (b).

Concerning the branch 21, high rate of V_r appeared in each parameter due to the variation of voltage magnitude beyond the limits. For the branch 40, V_r of the bus 28 is very high due to the effect of reactive power at the bus 8.

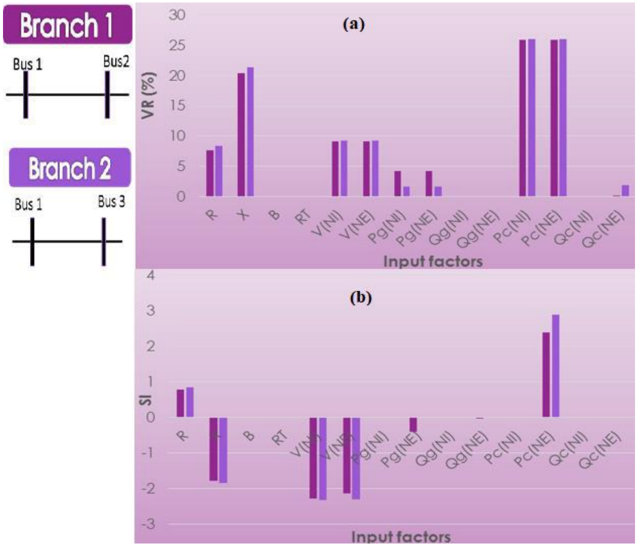

Fig. 6: Input factors in branches 1 and 2: (a) Relative variation rate, (b) Sensitivity Index

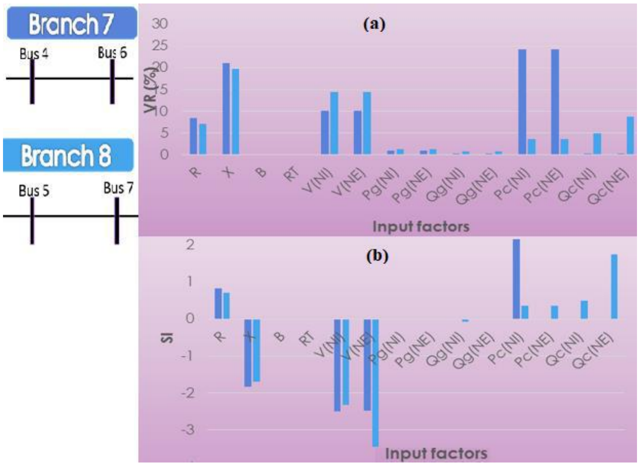

Fig. 7: Input factors in branches 7 and 8: (a) Relative variation rate, (b) Sensitivity Index

V. DISCUSSION

In this case by the given data from (Fig. 4),synchronous compensators are placed by network operators in buses 5, 8, 11 and 13. But according to the research of *Dharamjit and al.* [17], compensators are injected at the network in buses 13,22,23 and 27.

At this work, we have found that there is some issues related to voltage, generated and consumed reactive powers in buses 8,16,17 and 28. So, it will be better if any other energy sources or compensators are injected to these buses.

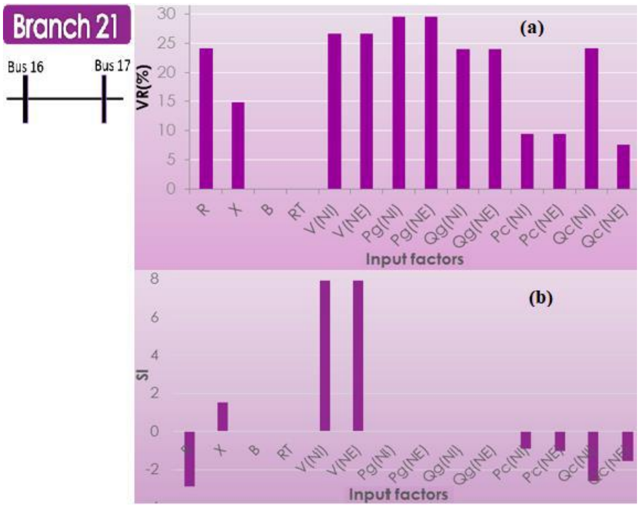

Fig. 8: Input factors in branch 21: (a) Relative variation rate, (b) Sensitivity Index

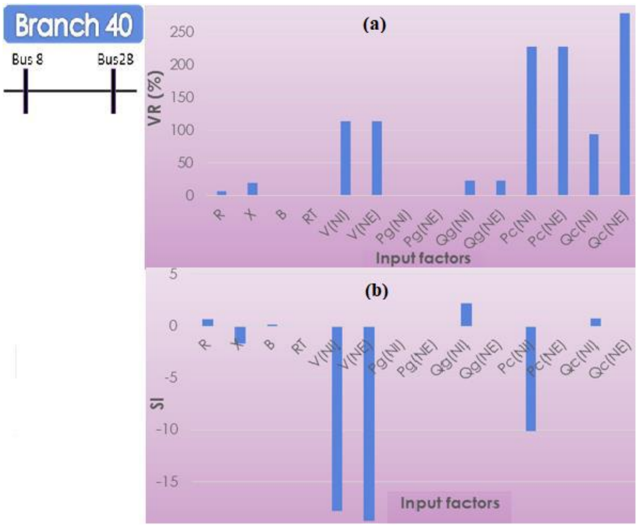

Fig. 9: Input factors in branch 40: (a) Relative variation rate, (b) Sensitivity Index

VI. CONCLUSION

Using NRLF method was chosen, in this work, to quickly assess the power losses on the 41 branches of the IEEE 30bus meshed distribution network. Identifying these losses with their influencing factors could help electricity distributors to find the issue of each branch in order to apply an optimization of their networks.

Among the parameters investigated of each branch during the analysis by OAT, the result shows that the most influencing parameters are:

- the consumed reactive powers;
- the bus voltages;
- and the linear parameters.

In fact, the application of OAT method also allows us to know the interdependence between the variations of bus voltage and the reactive power consumptions.

Concerning the required solution to optimize these losses problems, three mains suggestions are given such as:

- the reactive power compensation by using capacitor banks for the branch which have reactive powers issues;
- the injection of energy sources into the low bus-voltage, like hybrid system or renewable energy;
- the reconfiguration of the network according to the suitable loads if necessary.

Finally, the application of these proposal optimizations requires more economical and technical analysis in order to avoid excessive investment and meet demand.

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